Journal of Agrometeorology 6 (2) : 188 - 195 (Dec 2004)

An approach to retrieve and validate some land surface parameters using satellite images*

B. K. BHATTACHARYA, M.R. PANDYA and V.K. DADHWAL
Crop Inventory and Modelling Division, Agricultural Resources Group, RESIPA
Space Applications Centre, Ahmedabad – 380015, Gujarat, India

ABSTRACT

Retrieval of land (soil-vegetation complex) surface temperature (LST) and ground insolation was carried out over middle Gujarat region using VIS(channel 1), NIR(channel 2) and thermal bands (channel 4 and 5) and ground emissivity from atmospherically corrected NDVI of NOAA AVHRR LAC (1.1km x 1.1km) images. The atmospheric correction of VIS and NIR band reflectance to derive corrected NDVI was done using SMAC model. LST computed from split-window method were then compared with near synchronous soil and air temperatures using field observations made during 13 -17 of January and April, 1997 at five sites. The LST derived from NOAA AVHRR thermal channel data varied from 301.6 – 311.9K in January and from 315.8 –325.6K in April. In April, LST were found to be more close to ST which may be due to relatively poor vegetation growth as represented by lower NDVI values in April. The global ground insolation and its direct and diffuse components were retrieved using Heliosat and ESRA models applied to NOAA AVHRR GAC (4km x 4km) images.The satellite retieved direct or beam insolation during May was found to be overestimated to the order of 10-15%.

Key words: NDVI, LASPEX,

Ground insolation and land surface temperature (LST) are two important land surface parameters for computing energy and water fluxes such as evapotranspiration (ET) over crop canopy. LST generally refers to the skin temperature of the earth. For bare soil, it is soil surface temperature, and for fully vegetated condition it is canopy temperature or in sparse vegetation case , it is the average temperature of the vegetation canopy, vegetation body and the soil surface under the vegetation (Qin and Karnieli, 1999). Under the availability of Visible (channel 1), NIR(channel 2) and themal data (channel 4 and 5) of NOAA AVHRR, many studies have been carried out on retrieval of ground insolation, LST and the related ground emissivity from both technological aspects and application to specific areas (Becker, 1987; 1991; Seguin *et al*., 1994; Choudhury *et al*., 1995; Casselles *et al*., 1997; Menenti

*Paper presented in the National Seminar on "Agrometeorological Research for Sustainable Agricultural Production", held at G.A.U., Anand during 27-28 September 2001.

et al., 1999) . Very few studies have been carried out in India by Gupta *et al.* (1995) on retrieval of LST only using NOAA AVHRR data. But the validation or comparison of satellite retrieved ground insolation and LST with real-time ground observations is lacking.

Thus the present study was undertaken with an aim to retrieve ground insolation and land surface temperature (LST) using NOAA AVHRR visible, NIR and thermal bands and to validate these land surface parameters by comparing with real-time ground observations.

MATERIAL AND METHODS

Study area

Land Surface Processes Experiments (LASPEX) were carried out at five stations of Gujarat at Anand (22°35′N, 72°55′E), Sanand (23°04′N, 72°22′E), Arnej (22°40′ N, 72°15′E), Derol (22°40′N, 73°45′E), and Khandha (22°02′N, 73°11′E) encompassing 100km x 100km area during 13-17 th of each month from January to December, 1997 (Vernekar *et al.*, 1999). NOAA-14 AVHRR images (1.1 x 1.1 km resolution) of the study area were acquired to retrieve LST for 13-17th of each of January and April,1997, which are two representative months of summer and winter, respectively. NOAA-14 AVHRR GAC (4km x 4km resolution) images are also acquired for the study area during 13-17th May, 1997 for retrieving ground insolation. Intensive observations on various meteorological parameters throughtout the day at 30secs interval and at different heights were taken during 13-17th of each of twelve months of 1997 by installing micrometeorological towers at five LASPEX sites. The time of satellite passes were between 14:30-15:15 hrs. IST. The images were then radiometrically corrected and registered geometrically.

Atmospheric correction for NOAA AVHRR Visible (VIS) and near- infrared (NIR) bands

The satellite derived surface reflectances at visible and NIR bands were atmospherically corrected using SMAC model (Rahman and Dedieu, 1994).The inputs used to this model were angular geometry (view zenith, view azimuth, solar zenith and solar azimuth angles), top-of-atmospheric (TOA) reflectance at each of NOAA AVHRR VIS and NIR bands, surface atmospheric pressure,average ozone content, water vapour content from radiosonde data at Anand collected on each day, average aerosol optical depth at 550nm computed from dark surface (Saunders, 1990). The average ozone contents over the region of interest were 0.24 and 0.27 atm-cm during December and May respectively. As the five sites are within 100km x 100 km, the average values of those atmospheric inputs were used for all the five stations. With the help of the corrected surface reflectances, distributed NDVI outputs were derived which were further utilized for estimation of land surface emissivity.

Retrieval of land surface temperature (LST)

The brightness temperatures from NOAA AVHRR thermal channels (4 and 5) were derived using inverse Planck's function. LST were retrieved using well known local split window algorithm given by Becker and Li (1990) and surface emissivity estimated from atmospherically corrected NDVI (Sobrino *et al*., 2001). The flow chart of retrieval of LST from NOAA AVHRR was already outlined by Bhattacharya and Dadhwal (2003) in their recent work.

The unique characteristic of this algorithm is that it divides the surface into two physical patterns and considers their various contributions to the LST , while other algorithms view the surface as one pattern.

Retrieval of global insolation at ground and its components

Total ground insolation has been derived using modified Heliosat method (Rigollier & Wald, 1999) which determines clearness index (K) from the cloudness index (N). The cloudness index , which characterizes atmospheric transmittance, can be derived from the following equation:

$$N = (\rho^t - \rho)/(\rho_c - \rho) \quad \text{..... (1)}$$

Where, ρ^t = apparent albedo of each pixel as observed by the sensor. The albedo was derived from atmospherically corrected reflectances in VIS and NIR using narrow band-to-broad band conversion technique (Valiente *et al*., 1998); ρ = minimum value of apparent albedo for each pixel for a time-series (13-17th of April and January) of images; ρ_c = maximum apparent albedo within the particular date image.

Again,

$$K = 1 - N \quad \text{(Beyer et al., 1996)} \quad \text{..... (2)}$$

Global instantaneous insolation (G) at ground = K * G_0

Where, $G_0 = 0.7*I_0*\varepsilon * (\text{Sin}\gamma_s)^{1.15}$

I_0 = 1367 Wm^{-2} is the solar constant

ε = correction factor of the sun-earth distance

γ_s = solar elevation (in degrees)

The components of total ground insolation i.e. direct and diffuse insolation were derived using ESRA model (Rigollier and Wald, 2000). The Linke turbidity factor, which characterizes the turbidity of atmosphere, was derived for each pixel by fixing two extreme values of 2.0 (very clear atmosphere) and 7.0 (turbid atmosphere) and normalization of clearness index to obtain diffuse radiation component. The direct or beam radiation was obtained by deducting diffuse component from total radiation.

Under present studies, NOAA AVHRR GAC data were used for retrieval of instantaneous ground insolation for the period of 13 –17th May at 14:30 hrs IST.

RESULTS AND DISCUSSION

NDVI and its variation

The normalized difference vegetation

index (NDVI) data before and after atmospheric corrections for the five LASPEX stations on two representative dates of 14 January and 14 April 1997 corresponding to winter and summer seasons respectively are presentated in Table 1. NDVI values showed increase after atmospheric corrections on both the dates of January and April. They were relatively higher during January than in April . The atmospherically uncorrected and corrected NDVI values were varying from 0.19-0.43 and from 0.23-0.56 respectively on 14 January. But on 14 April, those varied from 0.12-0.36 and from 0.19-0.50 respectively showing substantial increase in NDVI after atmospheric correction. The atmospherically corrected NDVI values were then used to estimate channel 4 and 5 emissivities of AVHRR for further computation of land surface temperature. Recent studies on comparison of methods of retrieval of land surface emissivity by Sobrino *et al* (2001) showed that the atmospherically corrected NDVI - threshold approach of emissivity retrieval is the best operational method as compared to approaches involving temperature independent thermal spectral indices.

Since NDVI is a good measure of growth of vegetation, it is directly related to vegetation cover over soil. The fractional vegetation cover (not presented in the table) was computed by normalization of NDVI. It was relatively high on 14^{th} January (0.28-0.75) as compared to 14^{th} April when it varied from 0.22 to 0.67. In both the seasons, there was relatively higher NDVI over Anand followed by Khandha as compared to rest of the stations where a low and almost constant NDVI values and vegetation cover were found.

LST retrieval and its comparison with air and surface soil temperature

The derived land surface temperature (LST) images were put to correction by computing coefficient of fractional vegetation cover following the methodology adopted by Kerr *et al*. (1992) for arid and semi-arid conditions. This correction was done by fixing two extreme values of NDVI and LST corresponding to full cover vegetation and bare soil conditions. The corresponding atmospherically corrected NDVI values within the study area were 0.85 and 0.10 during January and , 0.75 and 0.08 during April 1997. The retrieved LST for full vegetation and bare soil cover were found to be 292.0K, 313.3K in January and 312.8, 330.0K in April.

The retrieved LST from NOAA AVHRR during 13-17 January 14:30 hrs IST and 13-17 April 15:15 hrs IST for LASPEX study area were compared with surface soil temperature (ST) at 2.5cm soil depth and air temperature (AT) (Fig. 1). The 1:1 line showed that during January, LST lie almost in the mid way between ST and AT. This may be due to relatively higher vegetation cover and lesser contribution from soil as indicated by relatively higher NDVI as compared to that in the month of April. LST were found to be close to ST on the higher side during April, but away from AT. Similar observations were also reported by Kaleita

Table 1: NOAA AVHRR derived normalized difference vegetation index (NDVI) at five LASPEX sites

Location	NDVI (uncorrected)		NDVI (corrected)	
	14 Jan 97 14:30 IST	14 April 97 15:15 IST	14 Jan 97 14:30 IST	14April 97 15:15 IST
Anand	0.434	0.358	0.56	0.50
Sanand	0.238	0.181	0.31	0.28
Derol	0.190	0.120	0.23	0.19
Arnej	0.285	0.181	0.33	0.28
Khandha	0.361	0.246	0.43	0.38

Table 2 : Satellite retrieved ground insolation (Wm^{-2}) over LASPEX sites using NOAA AVHRR GAC images at 14:30 hrs. IST on 13 May 1997

Stations	Direct or beam insolation	Diffuse insolation	Global insolation
Anand	1035	52	1087
Sanand	1015	61	1076
Derol	999	63	1062
Arnej	1059	44	1103
Khandha	972	76	1049

and Kumar (2000) when fractional vegetation cover was drastically reduced. The fact that the relatively poor vegetation growth as indicated by low NDVI in April seemed to have influenced LST to become more representative of soil surface and close to ST.

The above results indicate that in semi-arid conditions direct relationship between LST and air temperature may not always exist.

Retrieval of ground insolation and its validation

The global insolation at ground and its direct and diffuse components retrieved from NOAA AVHRR GAC images of the representative on selected date (13 May 1997) at 14:30 hrs. IST over LASPEX sites is presented in Table 2. The AVHRR derived global insolation was found to vary from 1103 – 1049 Wm^{-2}. The direct or beam and diffuse incoming radiation components were found to vary from 972 – 1059 Wm^{-2}

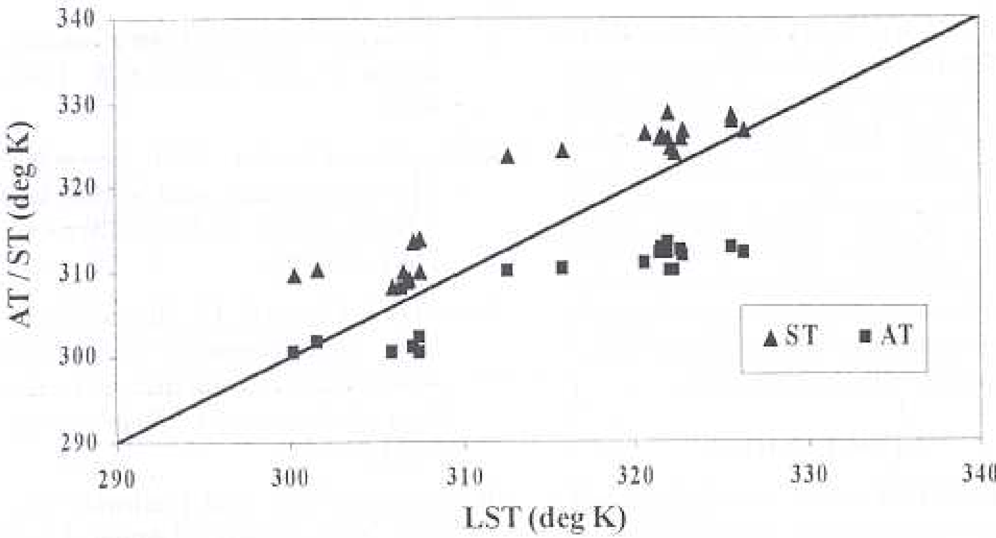

Fig. 1 : Comparison of LST with near air temperature (AT) and surface soil (at 2.5cm depth) temperature (ST)

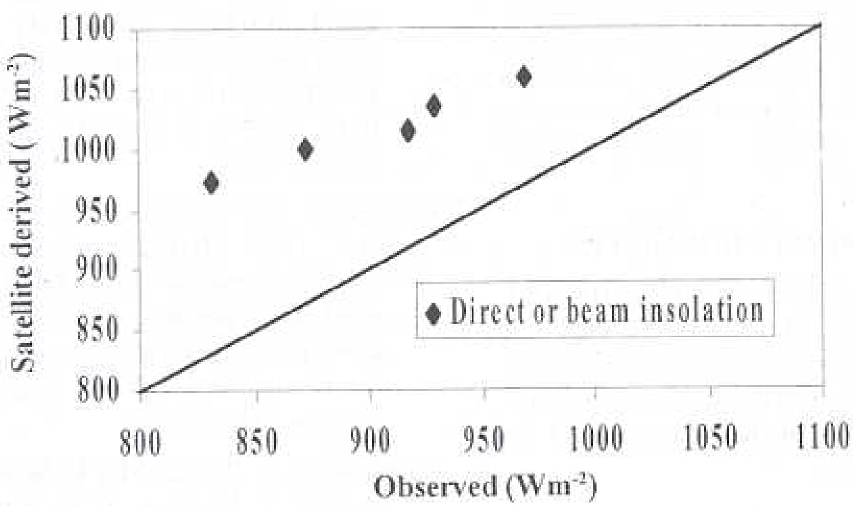

Fig. 2 : Comparison NOAA AVHRR derived direct insolation and ground observations

and 44 – 76 Wm^{-2} respectively. The NOAA AVHRR images derived direct or beam insolation was compared with ground observed data. The 1:1 line (Fig. 2) showed overestimates in satellite retrieved direct insolation across different stations to the order of 10-15% . The results suggested that modification of algorithm is further needed to obtain improved accuracy for its use in the studies of land surface processes using polar orbiting satellite data.

CONCLUSIONS

The NDVI values are relatively high in winter(January) than in summer (April) in the study region thus representing poor vegetation growth and more stressed canopy in summer than in winter. As the vegetation growth increases, the LST becomes more close to air temperature and when the vegetation growth is poor, the LST is more representative of soil surface temperature. The accuracy of NOAA AVHRR retrieved ground insolation using Heliosat method needs further improvement.

ACKNOWLEDGEMENTS

We are highly thankful to Dr. A.M. Shekh and his staff at GAU, staff of LASPEX for making the field observation data accessible to us and grateful to Shri J. S. Parihar and Dr. R. R. Navalgund for encouragement.

REFERENCES

Becker, F. 1987. The impact of spectral emissivity on the measurement of land surface temperature from a satellite. *Intern. J. Rem. Sensing*, 8: 1509-1522.

Becker, F. and Li, Z.L. 1990. Towards a local split window method over land surface, *Intern. J. Remote Sensing*, 11(3): 369-393.

Beyer, H.G., Costanzo, C., Heinemann, D. 1996. Modifications of the Heliosat procedure for irradiance estimates from satellite images . *Solar energy*, 56(3): 207-212.

Bhattacharya, B.K. and Dadhwal, V.K. 2003. Retrieval and validation of land surface temperature using NOAA AVHRR thermal images over Gujarat, India. *Intern. J. Rem Sensing*, 24(6): 1197 - 1206.

Casselles, V., Coll, C., and Valor, E. 1997. Land surface emissivity and temperature determination in the whole HAPES-Sahel area from AVHRR data. *Intern. J. Remote Sensing*, 18:1009-1027.

Choudhury, B.J., Dorman, T.J. and Hsu, A.Y. 1995. Modeled and observed relations between the AVHRR split window temperature difference and atmospheric perceptible water over land surfaces. *Rem. Sensing Environ.*, 51: 281-290.

Gupta, R. K., S. Prasad, M.V.R. Sesha sai and T.S.V. Nadham. 1995. Surface temperature estimation over agricultural region and its relationship with Normalized Difference

Vegetation Index using NOAA-AVHRR data. In: Proceedings of National symposium on " Remote sensing of Environment with emphasis on green revolution", PAU, Ludhiana Nov 22-24,1995.

Kaleita L. Amy and Kumar, P. 2000. AVHRR estimates of surface temperature during the 1997 experiment. *J. Geophy Res.*, 105 (D16) : 20791.

Kerr, Y.H., Lagourade, J.P., and Imbernon, J. 1992. Accurate land surface temperature retrieval from AVHRR data wiyh use of an improved split window algorithm. *Rem. Sensing Environ.*, 41: 197-209.

Menenti, Su Z., Pelgrum, H., Hurk, B.J.J.M. Van Den and Bastiaanssen, W.G.M. 1999. Remote sensing of land surface fluxes for updating numerical weather predictions. **In** : Operational Remote Sensing for Sustainable Development, pp 393-402.

Rahman, H. and G. Dedieu. 1994. SMAC: A simplified method for the atmospheric correction of satellite measuremens in the solar spectrum. *Intern. J. Rem. Sensing,* 15 : 123-143.

Rigollier, C and Wald, L. 1999. Towards operational mapping of solar radiation from Meteosat images. In: Operational Remote Sensing for Sustainable Development, pp 385-390.

Rigollier, C and Wald, L. 2000. Selecting a clear-sky model to accurately map solar radiation from satellite images. In : Remote Sensing in the 21st century : Economic and Environmental Applications, Casanova (ed.) pp 131-137.

Saunders, R.W. 1990. The determination of broad band surface albedo from AVHRR visible and near-infrared radiances. *Intern. J. Rem. Sensing,* 11 : 49-67.

Sobrino, J. A., Raissouni, N., and Zhao-Liang, Li .2001. A comparartive study of land surface emissivity retrieval from NOAA data. *Rem. Sensing Environ.*, 75:256-266

Valor, E. and casselles, V. 1995. Mapping of land surface emissivity from NDVI : Application to European, African, and South American areas. *Rem Sensing Environ*, 57:167-184

Vernekar, K.G., Sinha, S., Sadani, L.K., Sivaramakrishnan,S., Parasnis, S.S. 1999. Land surface processes experment in the sabarmati basin : an overview and early results, report no. RR-087, IITM, Pune, India.